Using Odor Science and Green Engineering to Better Control Odors

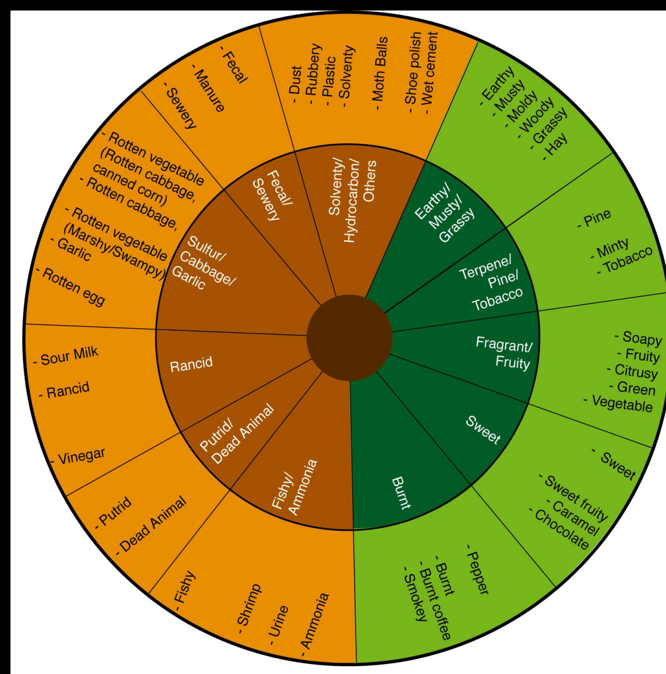
Marc Deshusses
Dept. of Chemical and Environmental Engineering
University of California Riverside

Mel Suffet
Environmental Science and Engineering Program
School of Public Health
University of California Los Angeles

Virginie Decottignies
CIRSEE
Research Center
Suez-Environment
Le Pecq, France

Outline

- Odors nuisance and relationship to odor control
- Controlling odors using high performance biotrickling filters
- Concluding remarks



Juliet tells Romeo that a name is an artificial and meaningless convention

"What's in a name? That which we call" … an odor

Odor is not a compound, hence it is defined by its attributes…

Odor concentration and intensity, often relative to a butanol scale

Odor character and hedonic tone using a pleasantness scale (poor, unacceptable, acceptable, good, excellent)

But what measures and defines an odor nuisance?

Odor nuisance can be defined as the odor character and intensity. But no standard methodology is used to measure nuisance

Proposed Method to Measure Odor Nuisance:

Odor character or quality: i.e. the specific odor character or quality and its specific odor intensity,

e.g. putrid, rancid, cabbage and musty

Odor quality intensity for each odorant: -weak, moderate, etc. on 1-12, or 7 point scale of threshold to very strong.

e.g. canned corn 8, rotten cabbage 6 and musty 2

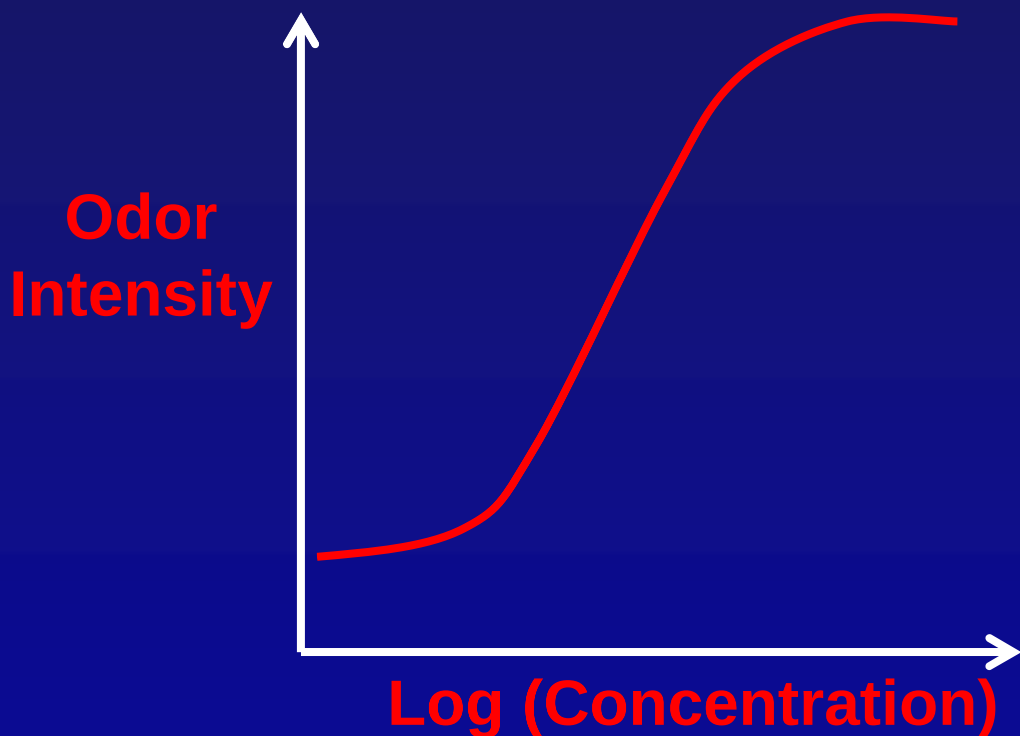
Odor Profile Method

- Judgment is made by selected and trained panelists as a team
- Breaks apart the overall perception into individual components
- Character “notes” are defined by references
- Numerical intensities define the strength of each “note”
- Method is labor intensive and “heavy” on panelists… all are supra-threshold measurements

Flavor Profile Analysis Intensity Scale

No Odor	0
Threshold	0 or 1
Very Weak	2
Weak	4
Weak-Moderate	6
Moderate	8
Moderate-Strong	10
Strong	12

Odor Intensity vs. Odorant Concentration



Odor Intensity =

m Log [conc.] + b

Weber-Fechner Law

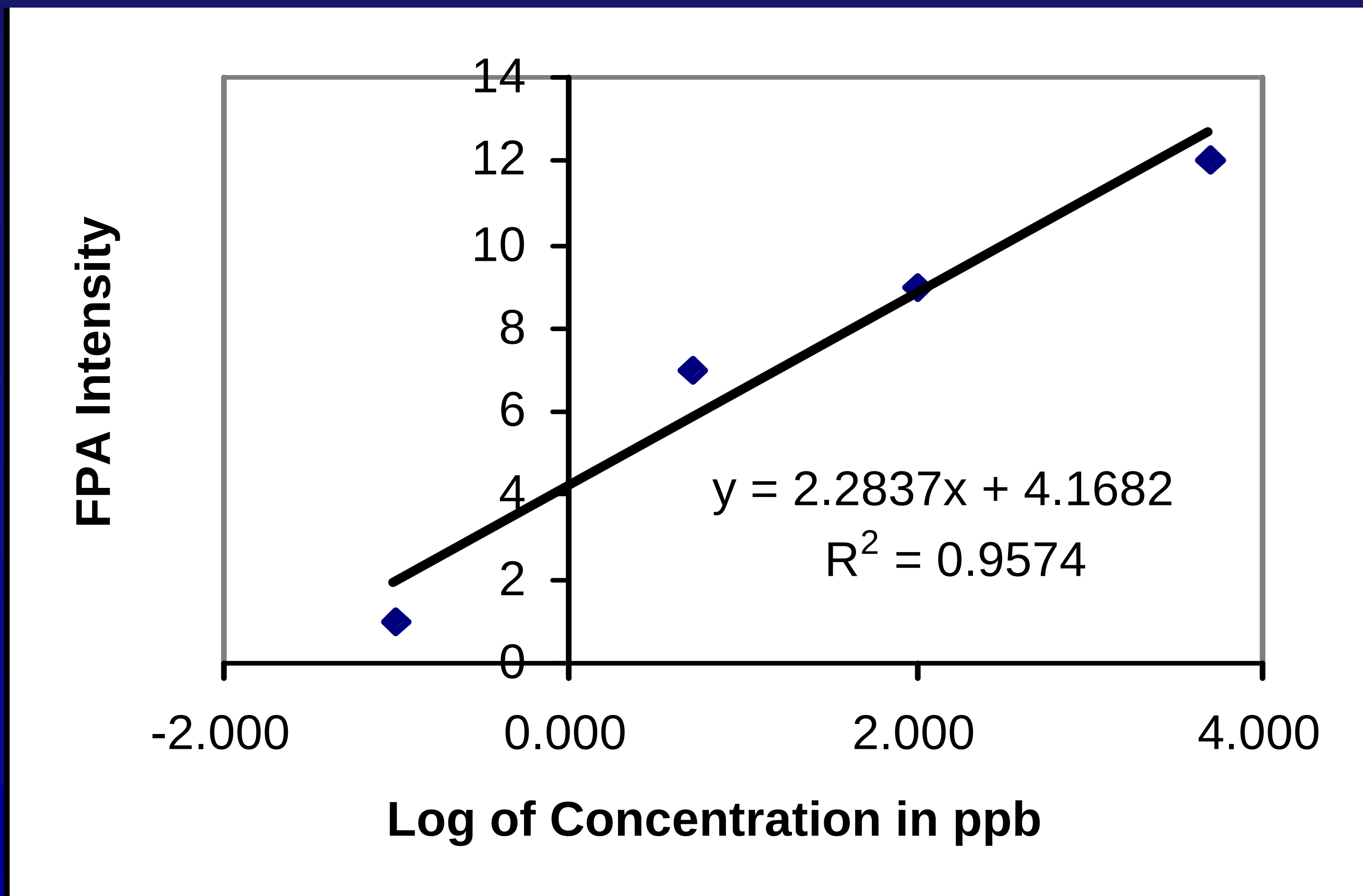
Log (Odor Intensity) =

m Log [conc.] + b

Steven's Power Law

- Semi-logarithmic relationship
- Different chemicals have different curves
- Different odors are diluted out at different rates

Odor Intensity of Dimethyl Sulfide

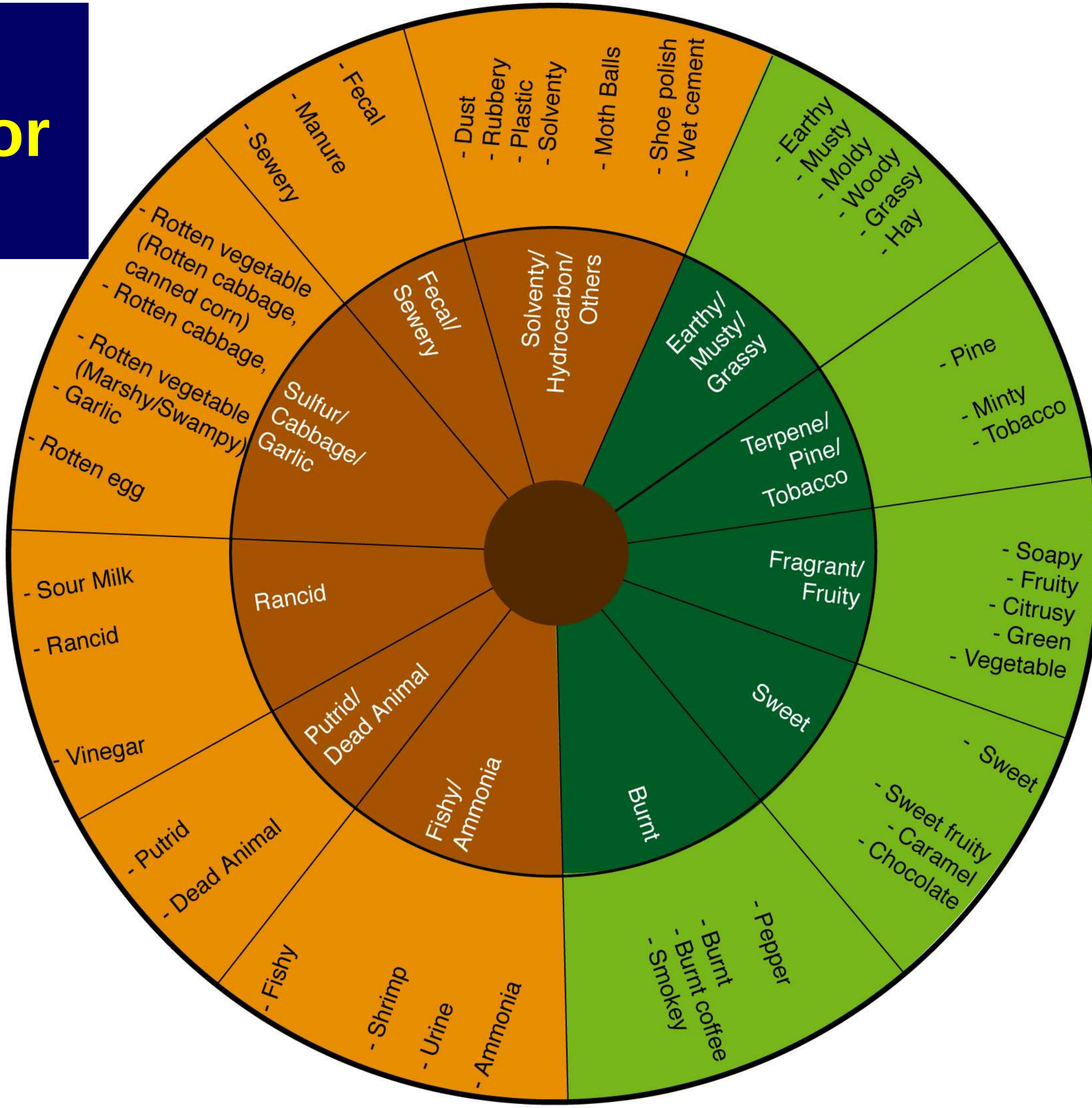


FPA = Flavor Profile Analysis

Sludge Drying Odor Wheel

1. Inside circle are "**Categories**"

2. Outside circle are **"Sub-categories"**



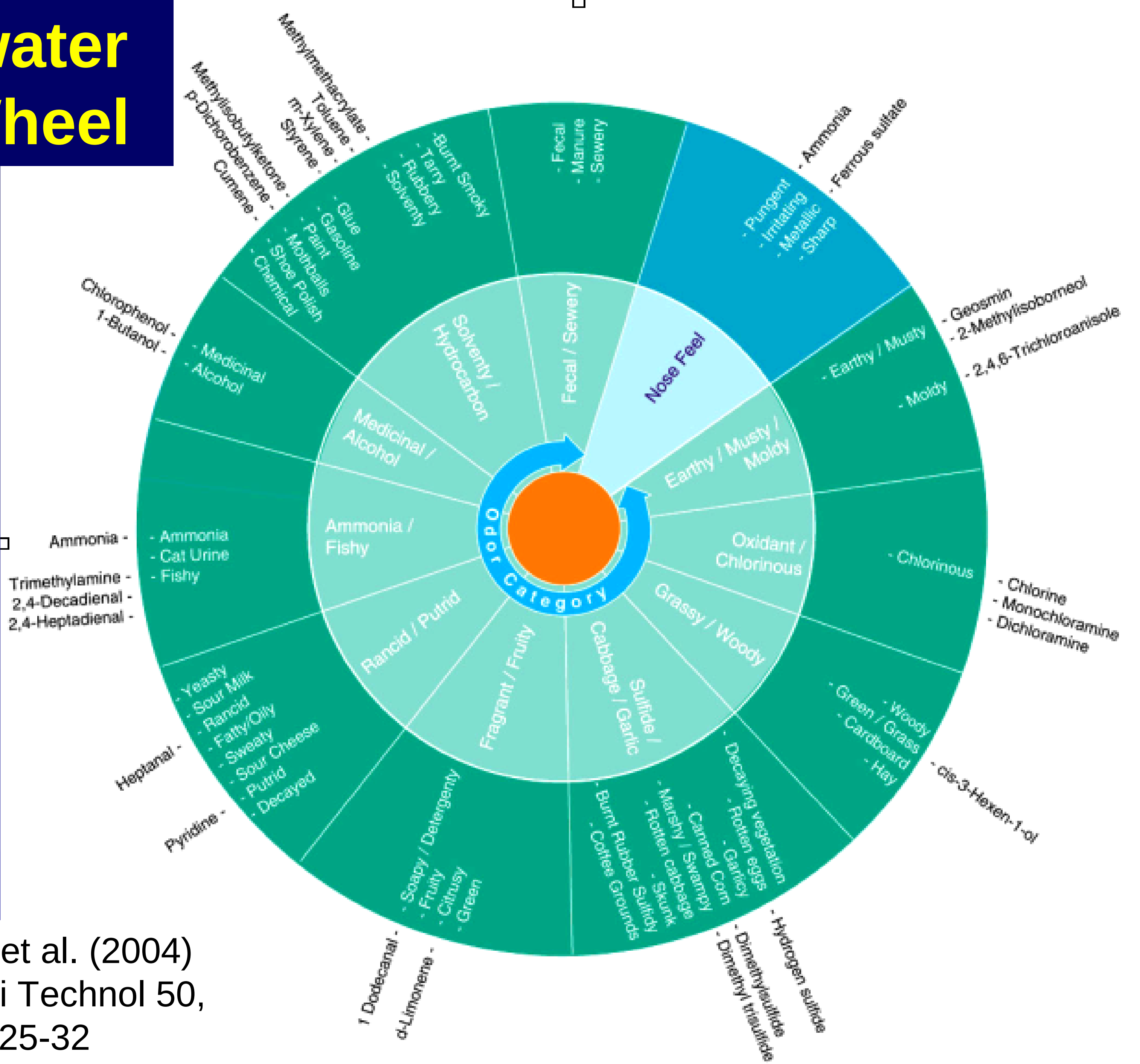
Suffet et al. IWA 2008 in press

Wastewater Odor Wheel

1. Inside circle are “Categories”

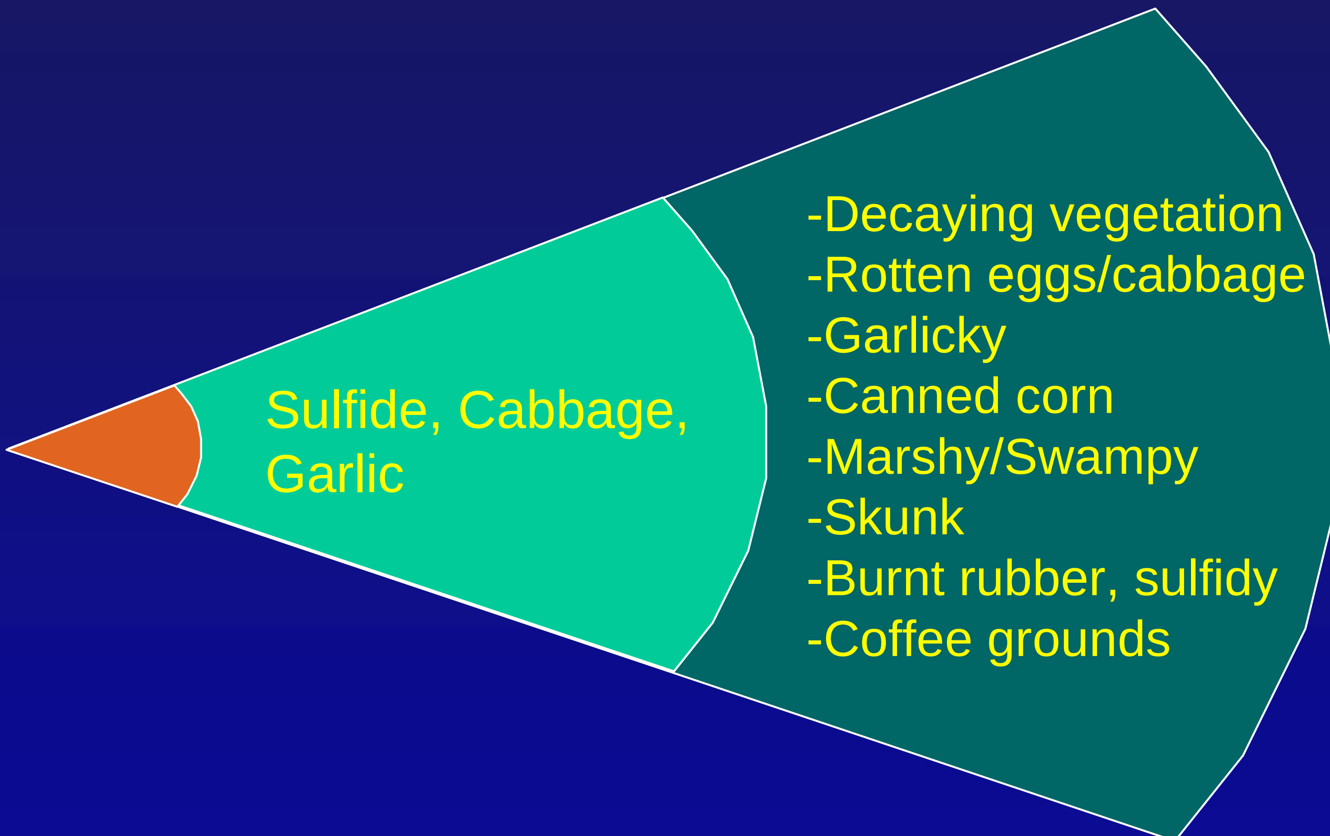
2. Outside circle are “Sub-categories”

3. Outside are identified causes to these odors



Suffet et al. (2004) Wat Sci Technol 50, 25-32

Wastewater Odor Wheel Detail



- -Hydrogen sulfide
- -Dimethyl sulfide and other reduced sulfur compounds

Use **odor notes, intensities and compounds responsible for odors to decide odor control strategy**

Example of Application

Wastewater treatment plant A		Wastewater treatment plant B	
Sources	Primary odor notes with their intensity	Sources	Primary odor notes with their intensity
Pumping station of raw water	Rotten eggs – 10 Rotten fishy – 8 Rancid – 8 Sewery – 6 Putrid – 4 Rotten vegetables – 4	Preliminary treatment	Rotten cabbage – 6 Rancid – 6
Primary settler	Rotten eggs – 8 Sewery – 6 Putrid – 6 Rancid – 4 Detergent – 4	Primary clarifiers	Rotten cabbage – 6 Vinegar - 4
Aeration basin	Rotten eggs - 6 Sewery – 6 Putrid – 4 Rancid – 2 Rotten vegetables – 2	Primary clarifiers	Rancid - 6

Implementation Challenges

- Train panel with suitable odor references (known, representative or substitutes)
  - Geosmin for Earthy
  - Trimethylamine for Fishy
  - Grass for Grassy
- Conduct selected chemical analyses and correlate with SPECIFIC odor panel observations
- Routine monitoring to determine odor nuisance, and to determine how control methods (and possible process changes) result in decreased (or increased) odor nuisances

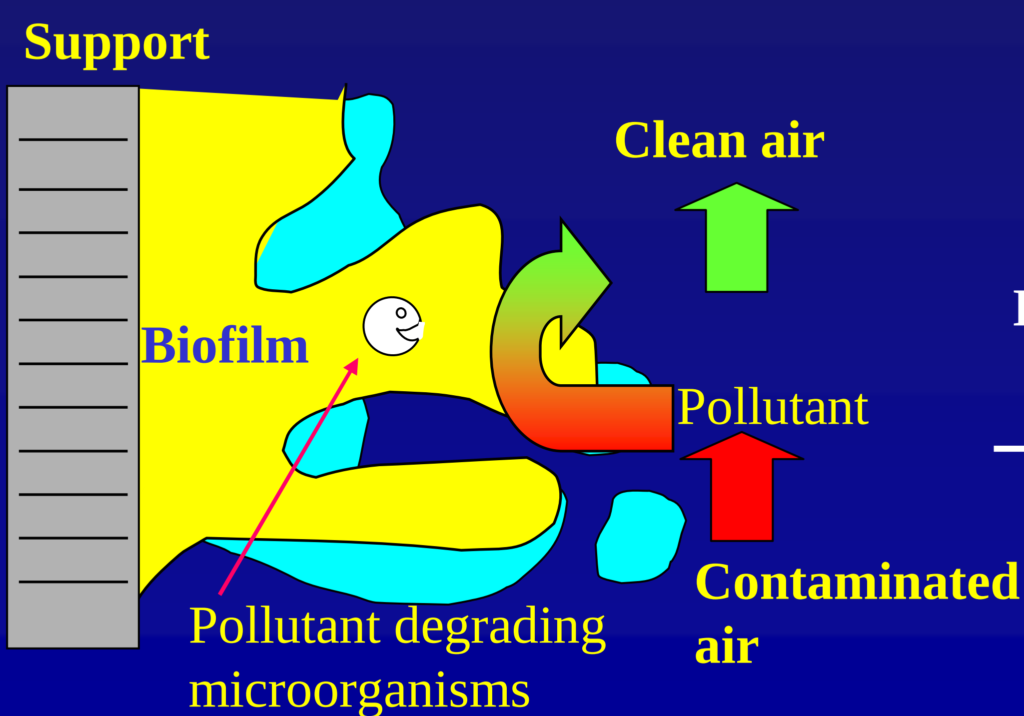
Odor Control Methods

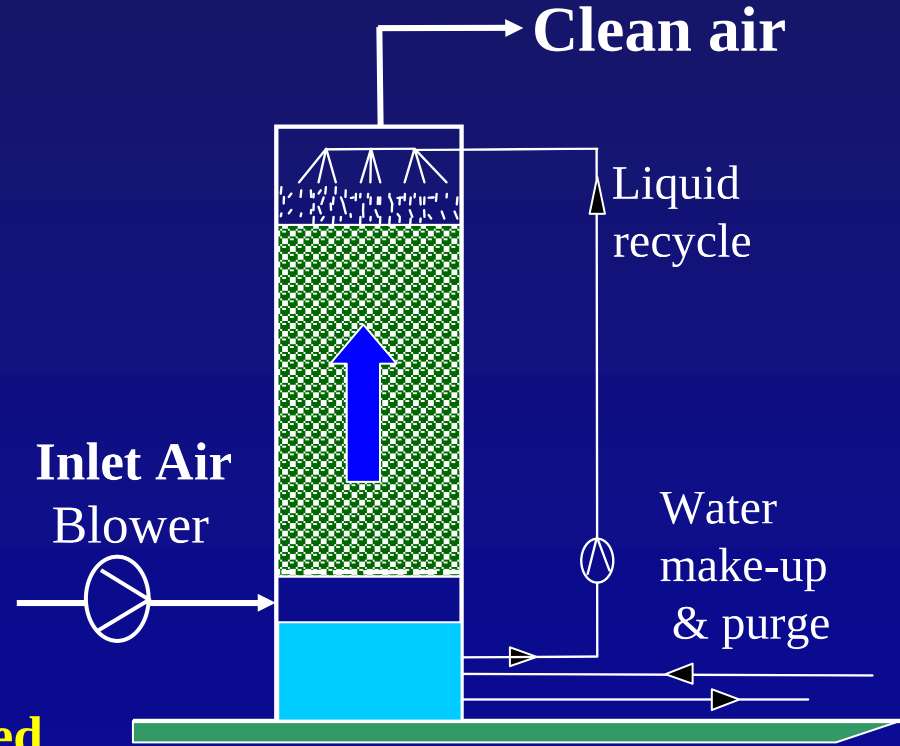
- Process modifications
- Dilution
- Masking
- Condensation
- Thermal oxidation

- Thermal oxidation
- Advanced oxidations
- Adsorption
- Chemical scrubbing
- Biological treatment
- etc.

Biotrickling Filters = Biological Scrubbers

$$H_2S + 2O_2 \xrightarrow{\text{bacteria}} 2H^+ + SO_4^{2-}$$





Comparison Chemical vs. Biological Scrubbers

Chemical scrubbers

$$H_2S \xrightarrow{2NaOH+4NaOCl} 4NaCl + Na_2SO_4 + 2H_2O$$

Biological scrubbers

$$H_2S \xrightarrow{+\,O_2+CO_2} 2H^+ + SO_4^{--}$$

$$\text{VOCs and organic odors} \longrightarrow CO_2 + SO_4^{--}$$

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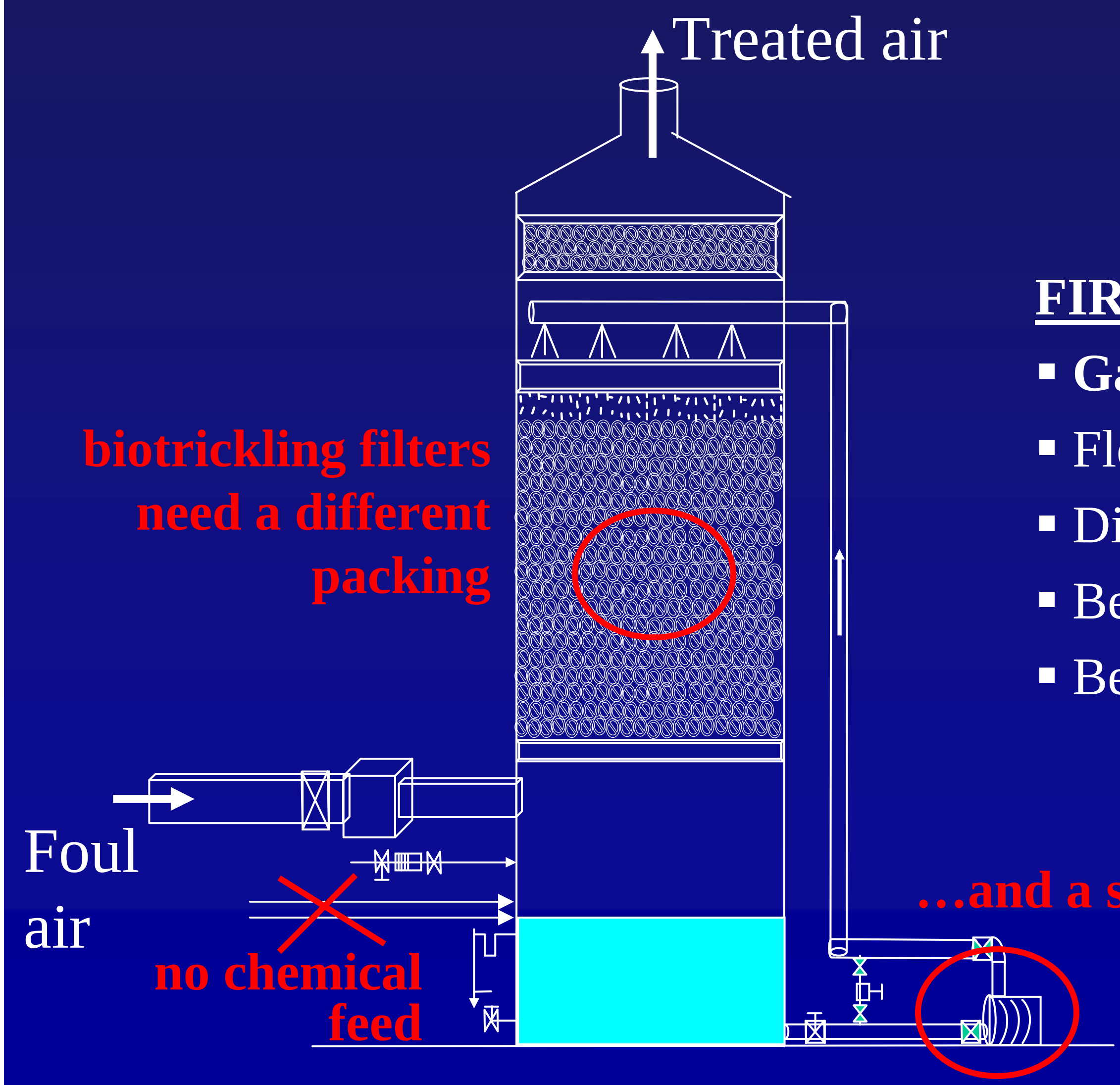
Can we convert existing chemical scrubbers to biological scrubbers?



FIRST SCRUBBER CONVERTED

- **Gas contact time = 1.6-2 sec**
- Flow rate = 10,000 cfm
- Diameter = 6 ft
- Bed height = 9-10 ft
- Bed volume = 7.3 m^3

University of California Riverside

OCSD together with UC Riverside converted 5 scrubbers (2001-ongoing)

- #10 Plant 1 10,000 cfm trunkline (roughing)
- #I Plant 2 10,000 cfm trunkline (roughing)
- #Q Plant 2 25,000 cfm primary (end-of-pipe)
- #J Plant 2 25,000 cfm dewatering (end-of-pipe)
- #G Plant 2 30,000 cfm DAFT (end-of-pipe)

- **Bed contact time 1.1 - 3 seconds!**

J

Q

G

Pictures from the actual conversion

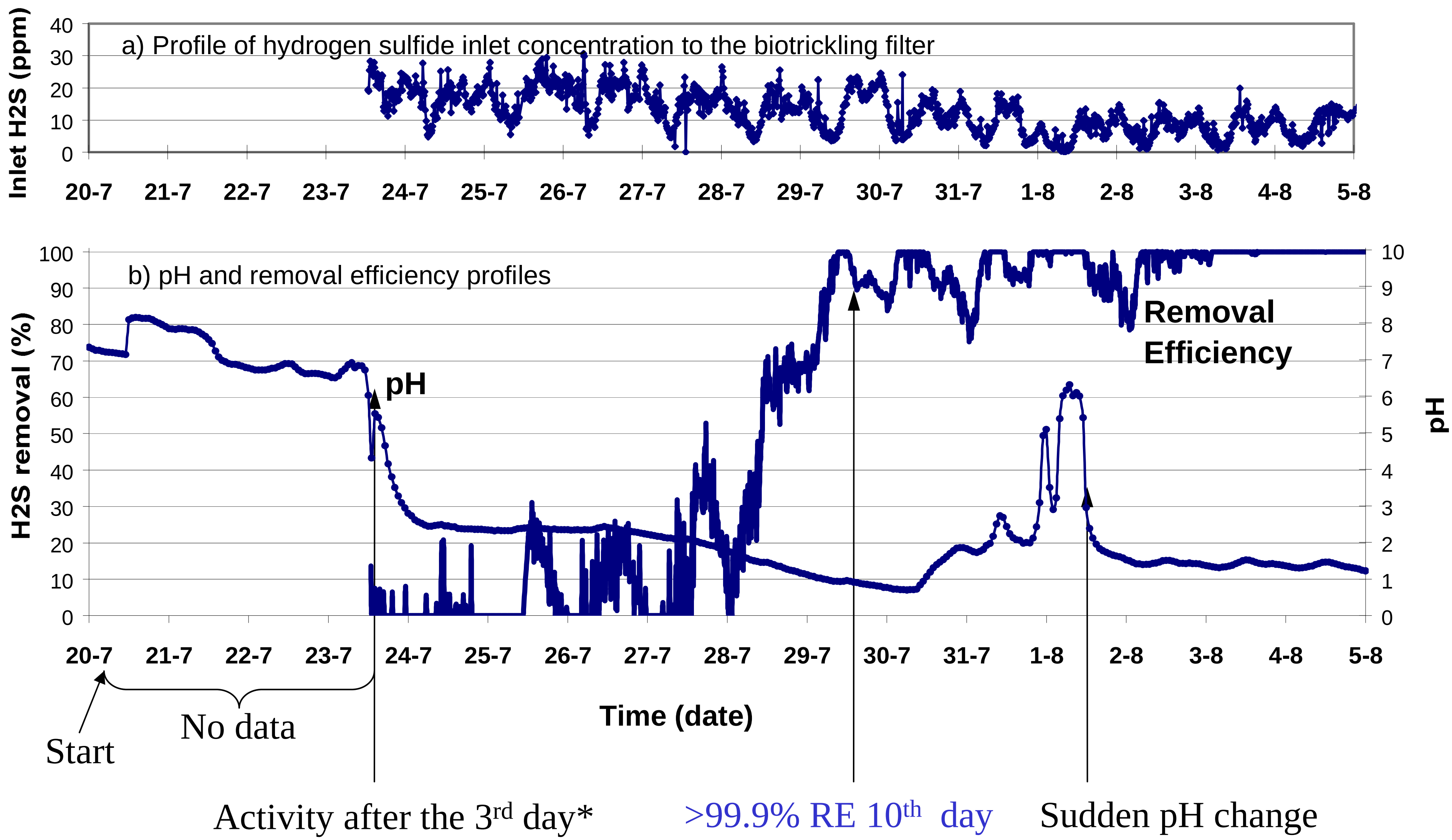
A 0.5 HP pump replaces the oversized 7 HP pump as trickling rate is reduced by about a factor 10

New packing installed

Polyurethane foam

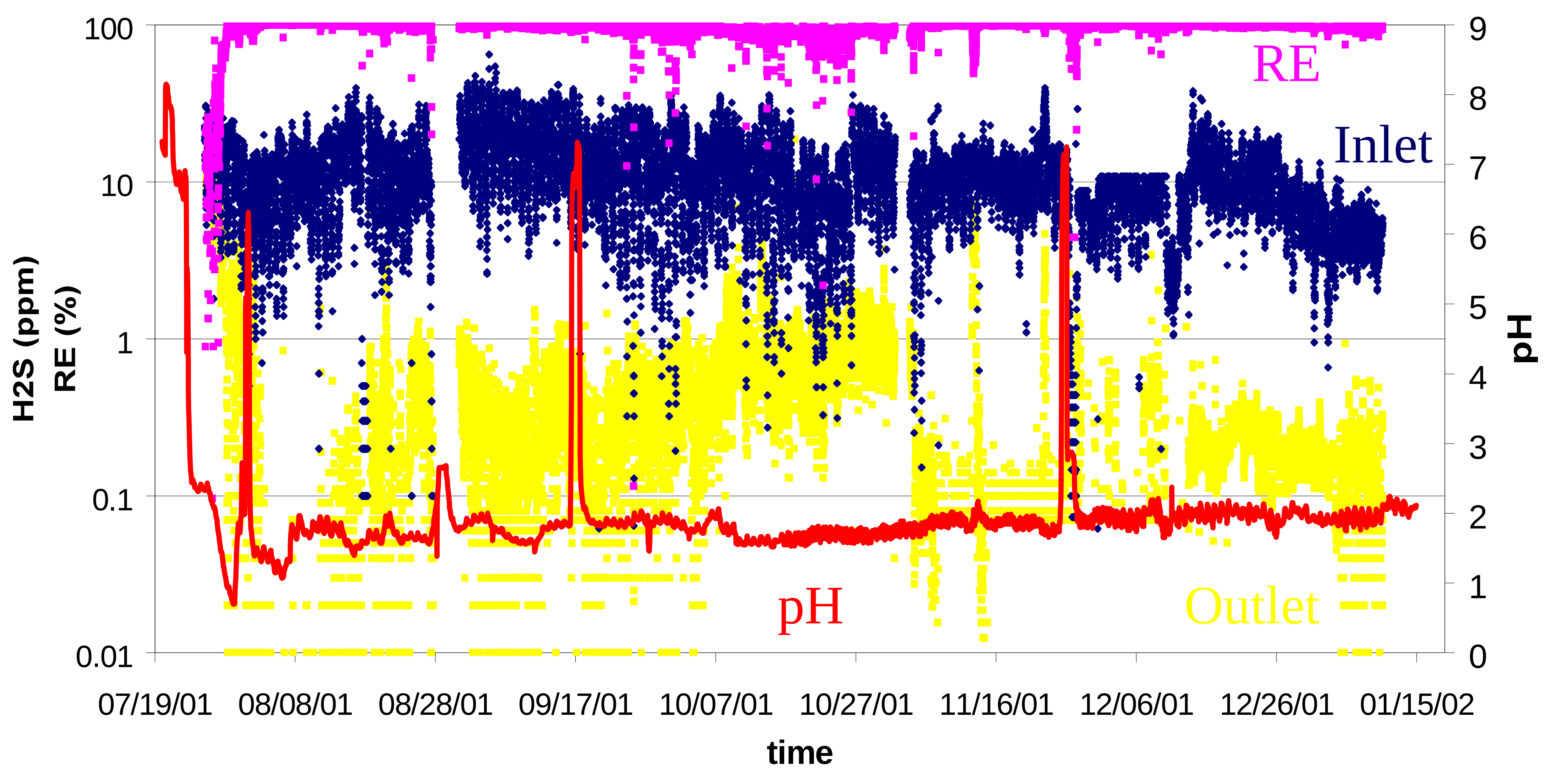
- Weight: ~ 30 kg/m^3
- Surface area: ~ 600 m^2/m^3
- Uses: Biotrickling filters

Effective removal is obtained 10 days after startup



(but optimum performance is obtain within hours after a restart)

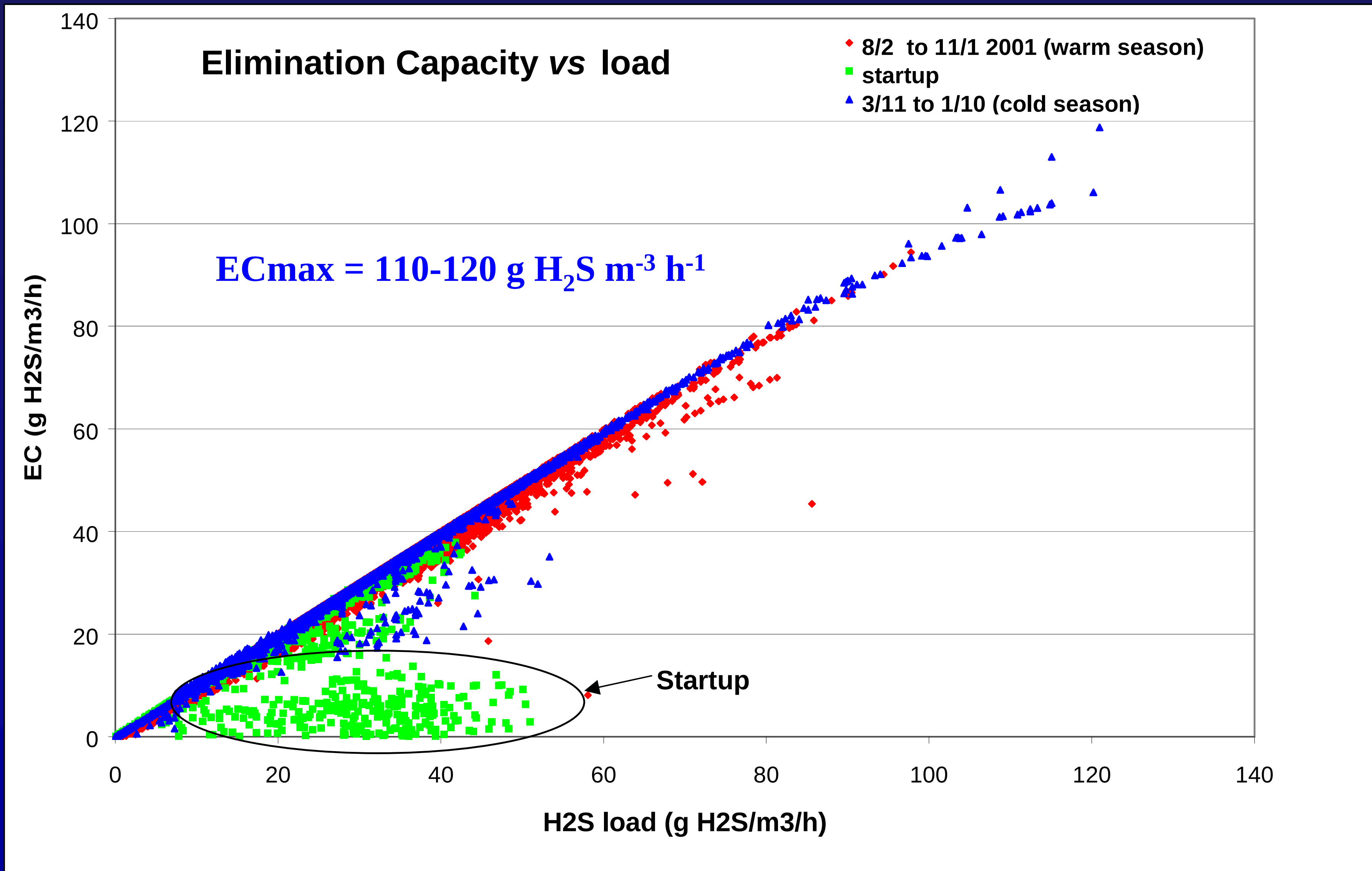
Long-term H_2S elimination capacity



No automatic control for water make-up supply

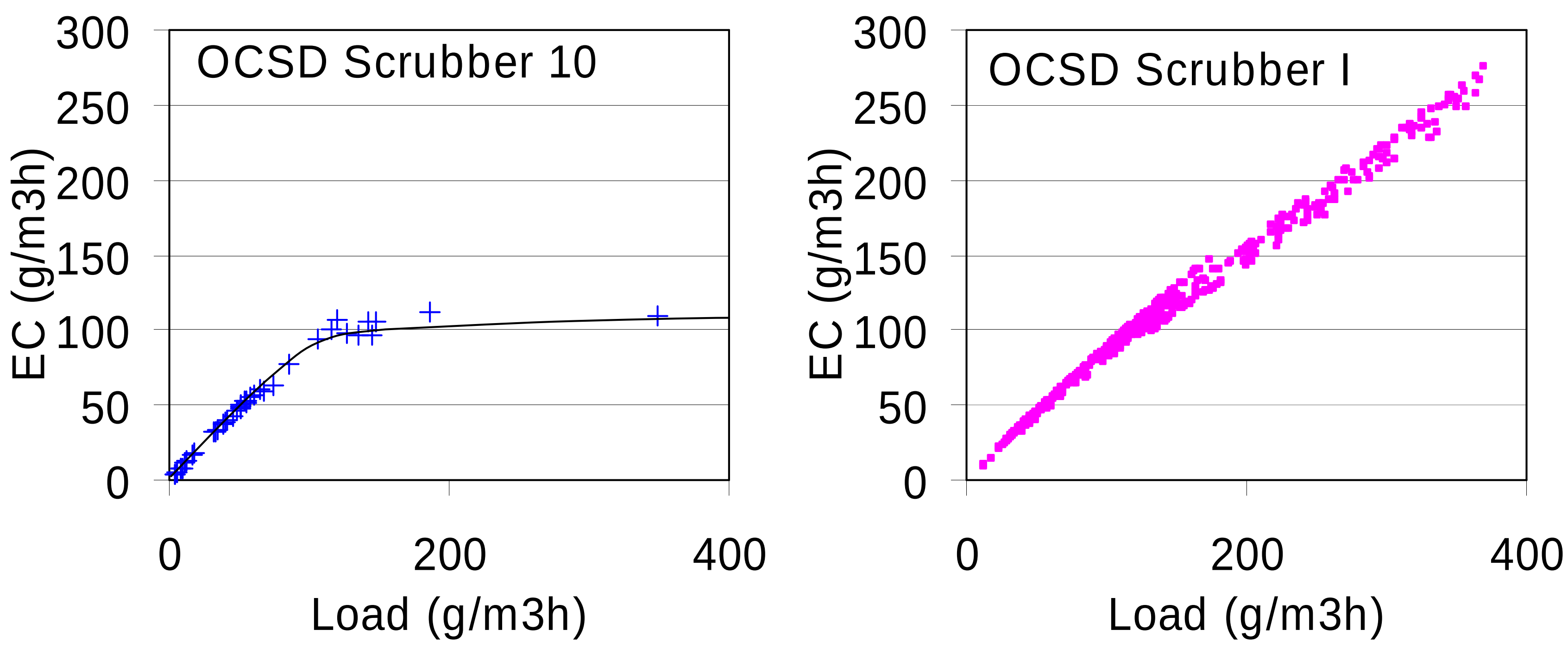
Outlet below 1 ppm (SC-AQMD limit) most of the time

Long-term H_2S elimination capacity

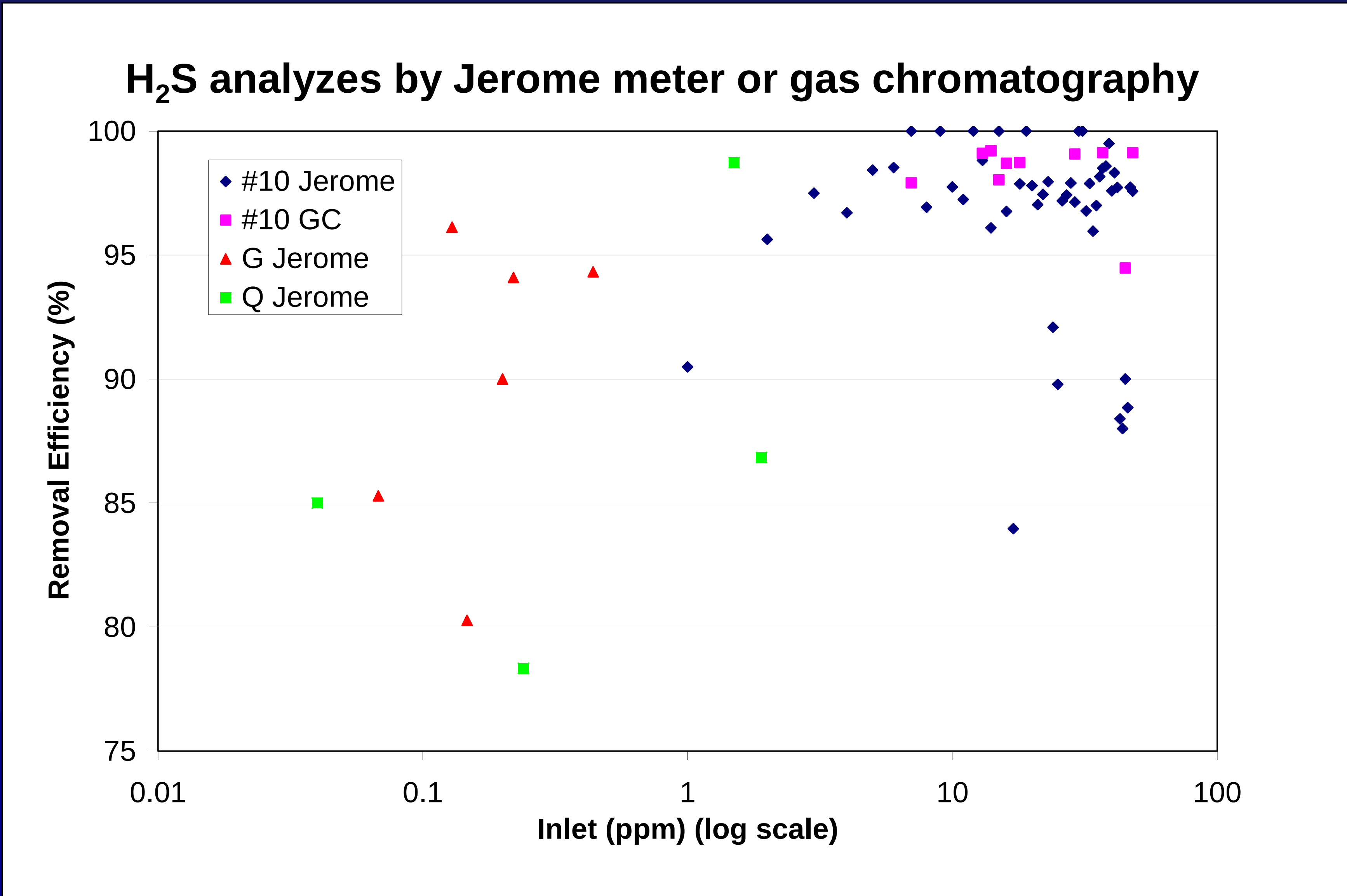


(Gabriel and Deshusses, Proc Nat Acad Sci USA 2003)

Even higher elimination capacities can be obtained at higher inlet H_2S concentrations



Effective treatment of low concentrations of H_2S is observed in all 3 biotrickling filters



Overall assessment shows that converted scrubbers are very successful… but why does it work so well?

97-99 % Removal at 1.6 – 2.2 seconds gas contact time

- Good packing material
- High mass transfer rate (tall bed, high velocity)
- Foul air well distributed across the diameter, no short-circuiting
- Enough nutrients and carbon dioxide, optimum conditions

H_2S… problem solved!
How about odors and VOCs?

- Removal of odorous compounds
- Odor removal efficiencies and relationship to H_2S
- Effect of conditions on odor removal

Odors at the trunkline scrubbers

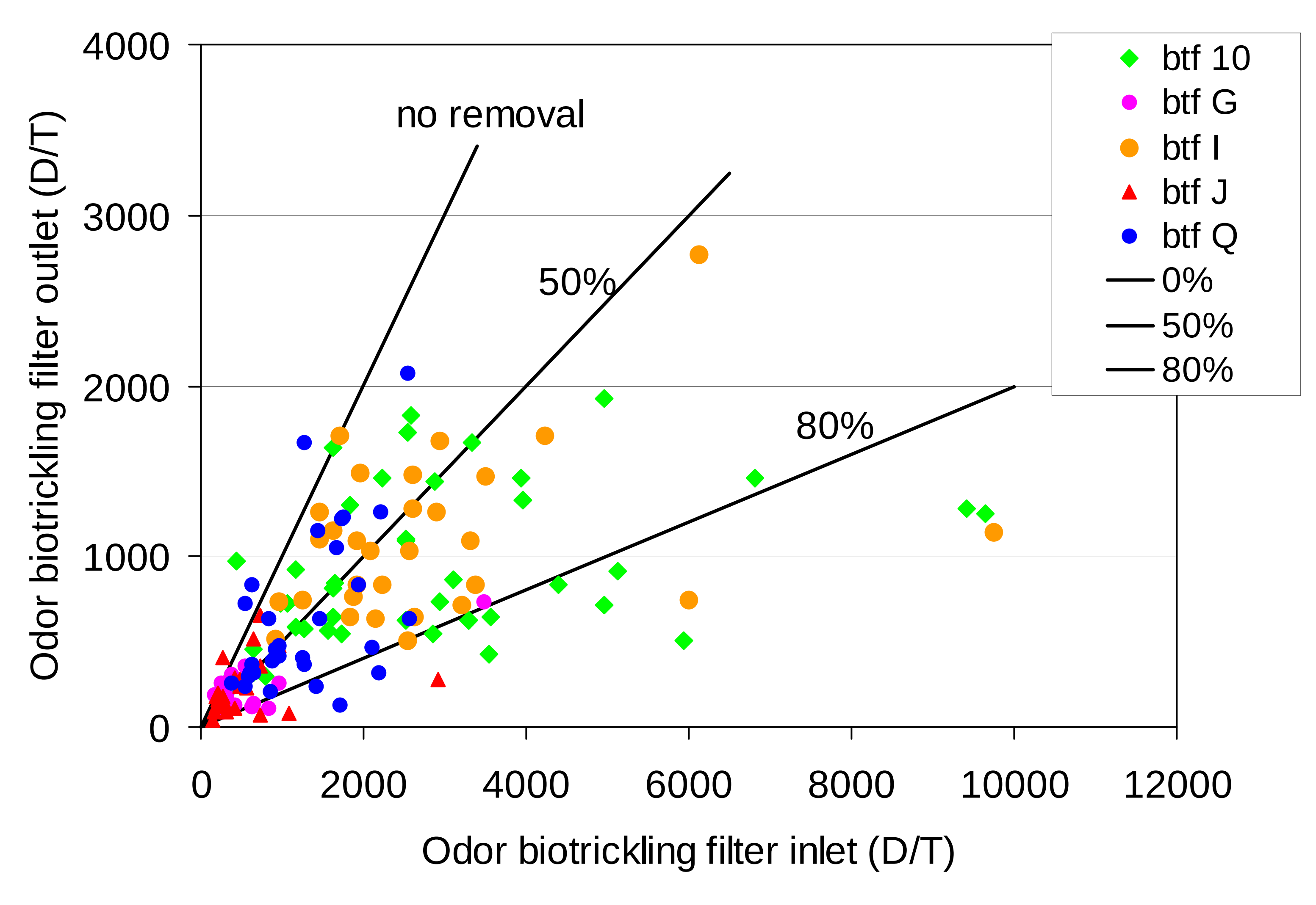
Compound	Inlet conc. (ppb_v)	Removal (%)
Carbonyl sulfide	67 ± 8	44 ± 11
Methyl mercaptan	193 ± 34	67 ± 11
Carbon disulfide	70 ± 21	35 ± 5
Methylene chloride	132 ± 93	36 ± 25
Toluene	753 ± 214	29 ± 14
m+p xylene	480 ± 852	41 ± 19
Odor (D/T)	1980 ± 480	65 ± 21

(limited data set N~20)

Other compounds <u>expected but not measured</u>: indoles, skatoles, terpenes, cresols, organic acids, nitrogen compounds…

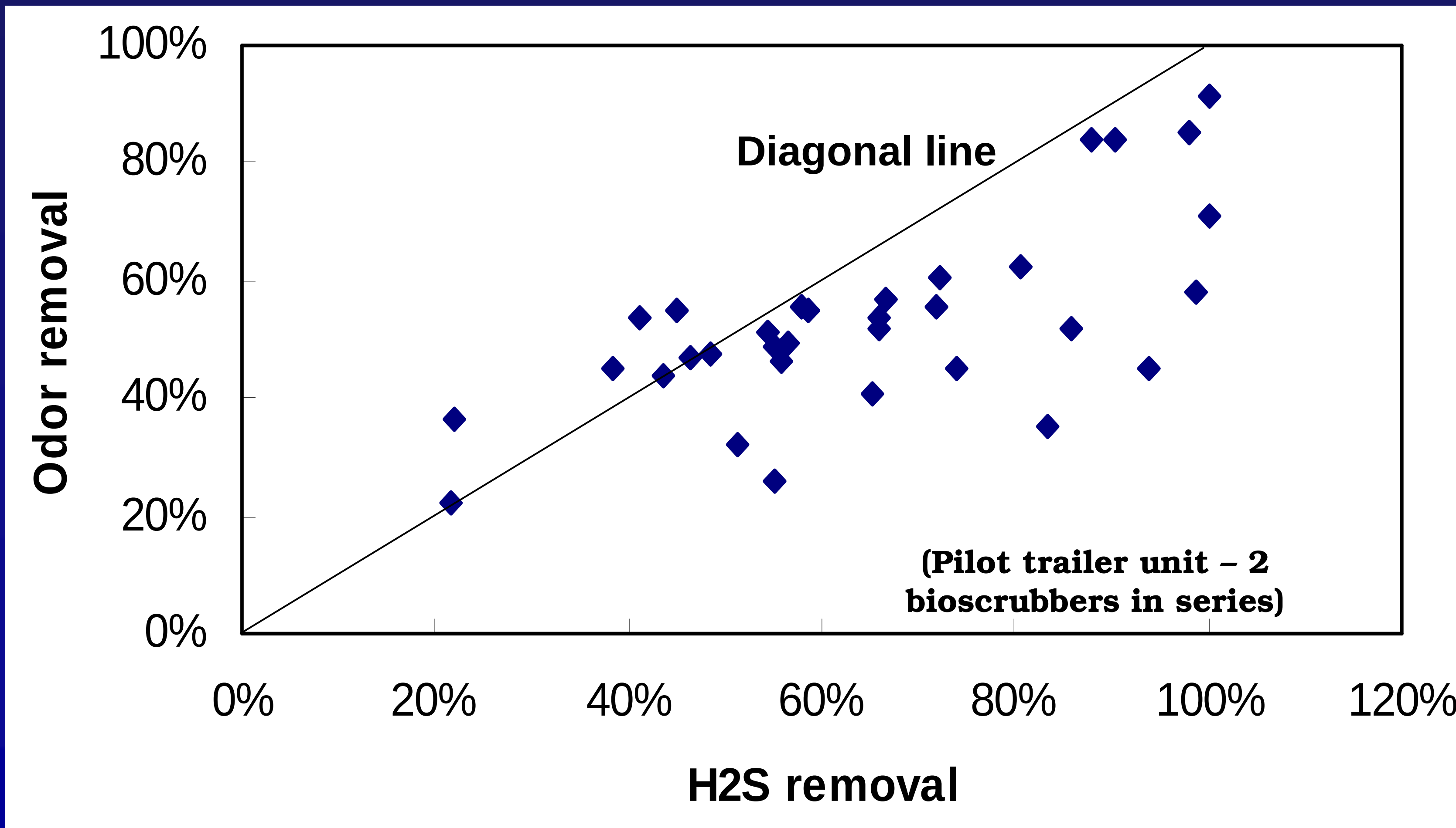
Treatment of odors shows large spread

5 scrubbers, ~300 odor samples over 2 years



Note: LACSD odor panel, DT not normalized

Treatment of odors correlates with H_2S removal, but…

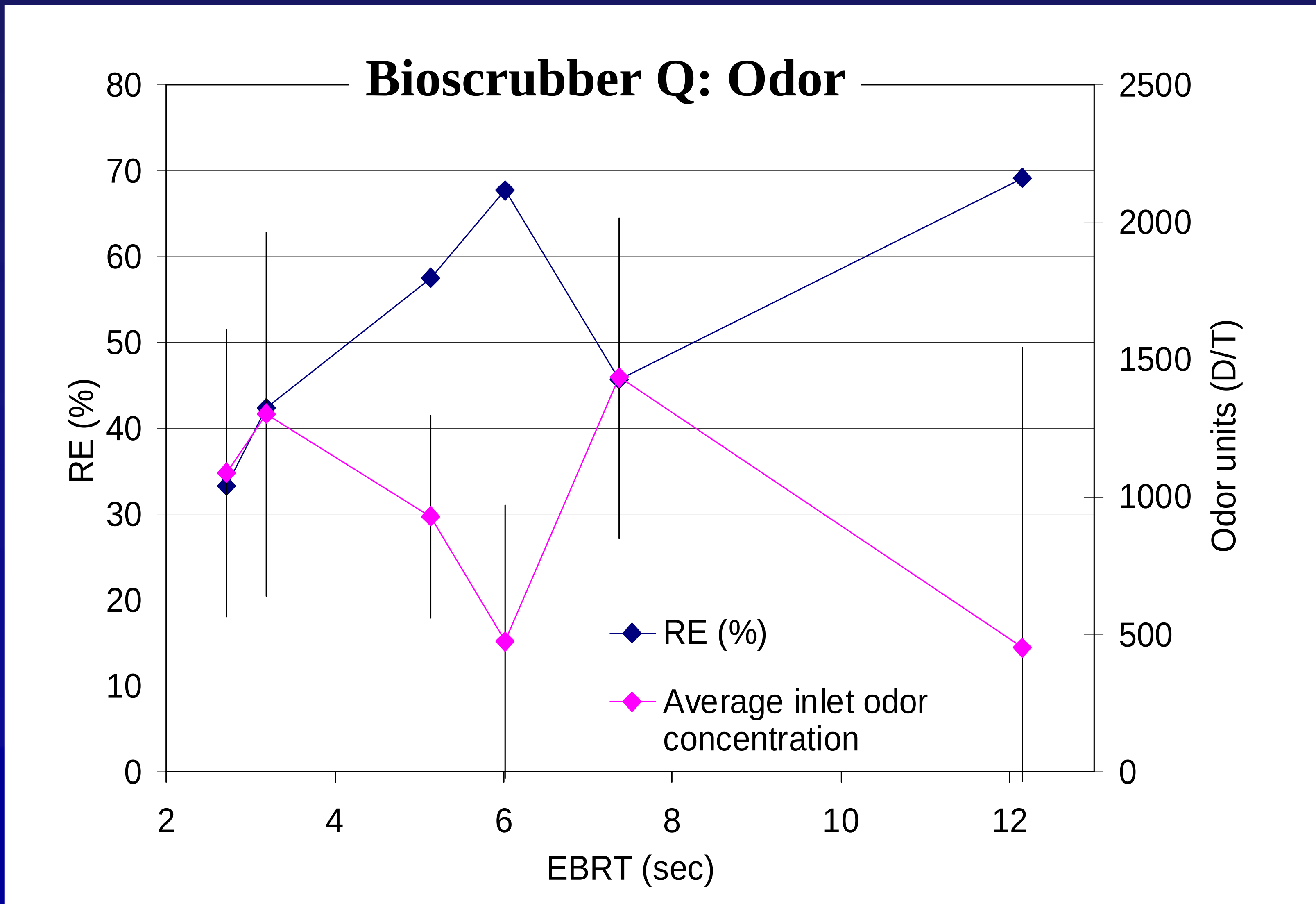


Note: UCR odor panel, DT normalized

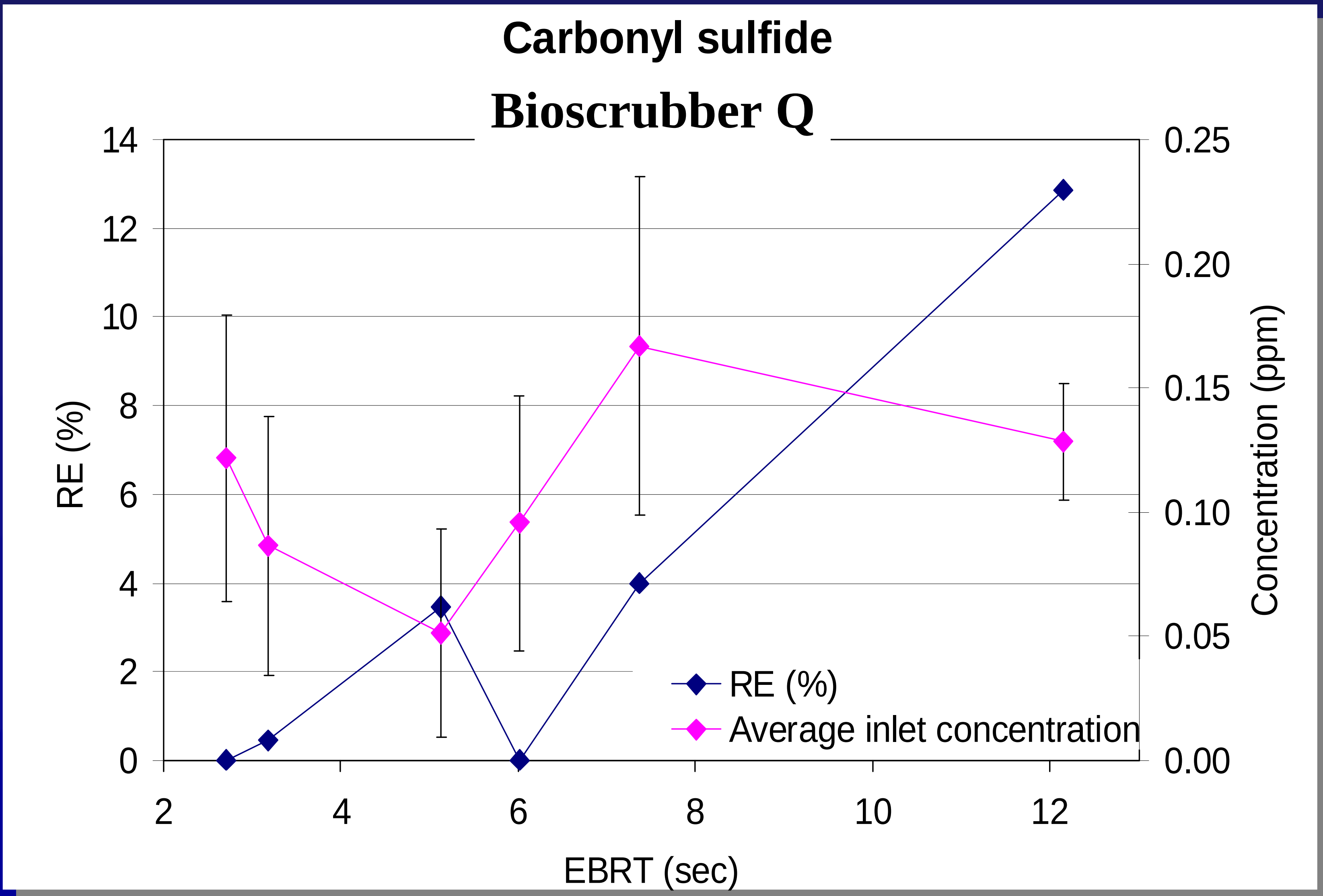
Effect of gas residence time (EBRT) on odor treatment

- Scrubber Q (at the primary treatment, polishing scrubber): low H_2S, medium RSC and VOCs

Effect of gas residence time on treatment



Effect of gas residence time on treatment



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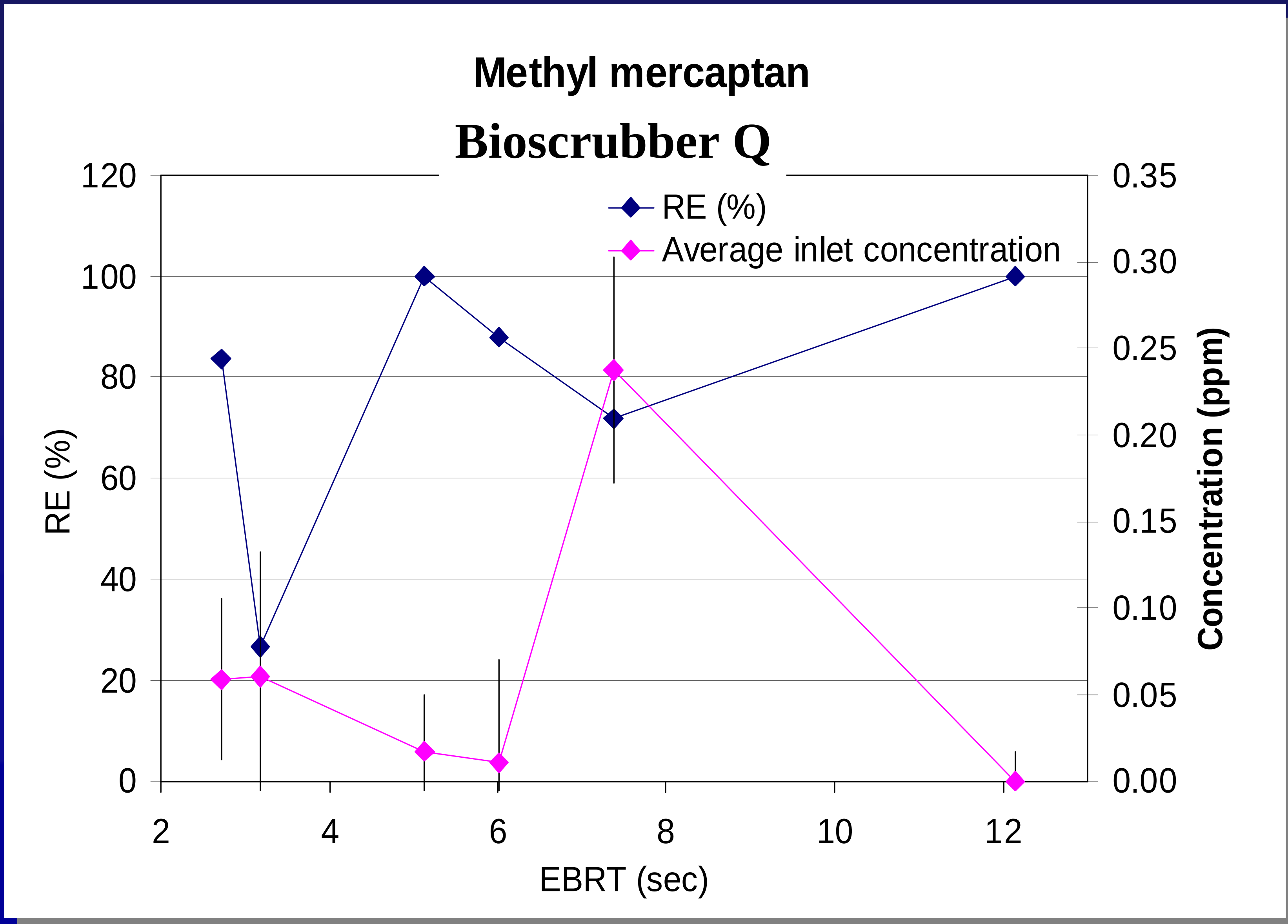

OCSD New Odor Control Facilities

	Process Location	Foul Air Capture (cfm)	# Roughing Biotowers	# 1st Stage Biotowers	# 2nd Stage Chemical Scrubbers
Plant No. 1	Influent Structure	57,000	3	0	0
	Headworks	119, 000	0	5	4
	Primary	118,000	0	4	4
	Solids Processing	80,000		4	
Plant No. 2	Influent Structure	40,000	3	0	0
	Headworks	188,000	0	13	8
	Primary	130,000	0	6	5
	Solids Processing	125,000		7	
	Total	**857,000**	**6**	**39**	**21**

Conclusions

- Odor science is progressing. Odor characters, intensities, and chemical composition are important descriptors to develop an odor control strategy.
- Chemical scrubbers can easily be converted to high performance biotrickling filters. Biotrickling filters can be very effective, they are economical and environmentally friendly.
- Residual odor poses challenges. Successful treatment of residual odor requires a detailed characterization of the odor, study of odor treatment under well controlled conditions, and good engineering

Acknowledgments

Suez-Environment, France
Orange County Sanitation District

Contacts

msuffet@ucla.edu
mdeshuss@engr.ucr.edu